Demonstration of a KIER Type CYBAGFILTER System at the Ssangyong Cement Yongwal Plant

Young-Ok Park, Sang-Do Kim, Jae-Ek Son[1] and Young-Woo Rhee[2]

[1] Energy & Environment Research Department,
Korea Institute of Energy Research, Taejon, Korea
[2] Dept. of Chemical Engineering, Chungnam National University, Taejon, Korea
E-mail: yopark@kier.re.kr, Tel: +042-860-3620, Fax: +042-860-3134

ABSTRACT

A high performance KIER TYPE CYBAGFILTER that combines a fabric filtration and centrifugal dust removal technologies was developed to maintain high performance of the existing bag filter. Based on the performance results obtained from a pilot-scale test unit and fluid dynamics computer simulation, a test CYBAGFILTER of 18,000m^3/hr capacity was installed in the clinker calcination process of Yongwal Ssangyong Cement Co. A surface filtration membrane filter was applied and evaluated. Mean pressure drop was 35mmH_2O, collection efficiency was more than 99.84%, and mean exit dust concentration was 0.23mg/Sm^3. Based on 100mmH_2O pressure drop the cleaning interval was much longer than that of existing ones by 20-40 times, promising the prolongation of filter life.

BACKGROUND

Dust particles are known to be the most harmful to the human body among air pollutants and make the visual range short. Most of them are generated from oil and coal combustion processes, wastes incinerators, and various manufacturing processes such as automobiles, steel, and cement industries. In order to eliminate dust particles several types of dust removal apparatus such as fabric filters, electrostatic precipitators, centrifugals, and scrubbers are used, one of which, however, can not fully meet the recently reinforced stringent air emission standard. Therefore, a hybrid type particulate collection technology consisting of more than two of these existing dust removal technologies is being extensively studied [1,2].

It is well known that fabric filtration gives high performance especially for fine particles compared to other dust removal methods. However, as shown in Fig. 1, a pre-dust collector such as centrifugals should be installed to reduce dust loading to the fabric filter in order to maintain high performance of fabric filter. Such an additional installation of pre-dust collector requires additional space, cost, and sophisticated control, which are hardly acceptable.

Recently, in order to solve this kind of problem KIER has developed a KIER-type CYBAGFILTER that combines the principles of centrifugation and fabric filtration. The fabric filter is located at the top of the CYBAGFILTER while the centrifugal at the bottom. This combination and arrangement will generate 'three dimensional vortex flow', where dust particles after dust removal operation will easily fall down to the bottom of the apparatus [3,4].

In this study several key features of the CYBAGFILTER of 18,000m^3/hr scale installed at the clinker calcination process of the Yongwal Ssangyong Cement Company were investigated. Also, its design parameters were investigated such as pressure drop, dust collection efficiency, outlet dust concentration, and fractional dust collection efficiency in order to establish optimum operation and design conditions of the CYBAGFILTER

EXPERIMENTAL

Apparatus

As shown in Fig. 2, the inner tube was installed, which plays a role of the centrifugal outlet. The length and diameter of the inner tube and the angle between the inner tube and outer tube significantly affected the filter performance, which have been confirmed in the computational fluid dynamics simulation and pilot-scale experiments. Based on this preliminary study CYBAGFILTER test unit is constructed as shown in Fig. 3.

The test unit consists of dust air injection, main body, cleaning air supply, dust removal, and clean air outlet. The diameter of CYBAGFILTER is 3,100mm and its total height is 7,535mm. The pulse-jet type cleaning method was applied. A fresh air damper was installed at the inlet of the test unit to prevent hot cement clinkers from directly flowing into the test unit, which can be caused by an abnormal operation. Whenever the inlet gas temperature goes up to a certain level, the damper will be open automatically and the fresh air will flow in. The cold fresh air will drop the temperature of the hot clinkers and eventually the damage of the filter will be avoided

Filter

A membrane filter was used for the test unit, which has been developed by the cooperation of KIER, Korea Virin Inc., and Wooda Inc.. Since the surface of the membrane filter is coated with acryl or PTFE (Polytetrafluoroethylene, Teflon) it has microporous structure which will prevent fine particles from penetrating inside the filter, therefore so-called 'surface filtration will occur. Also, it has low pressure drop due to low penetration resistance and its dust collection efficiency is above 99.9%[5]. In this study acryl was used as a filter surface coating material and polyester was used as a support. Maximum operating temperature the filter can endure is 120 . The diameter and length of one filter are 156mm and 3300mm. The test unit has 144 filters whose total area is 233m^2. Physical properties of the filter are summarized in Table 1.

Table 1. Physical characteristics of membrane filter.

Filter material	Polyester
Surface coating material	Acryl
Weight, g/m^2	570
Thickness, mm	2.0
Air permeability, cc/cm^2/sec	12 15
Tensile strength, kg/cm^2	MD : 90, CD : 240
Tensile strength, %	MD : 25, CD : 20
Bursting strength, Kg_f	35
Heat resistance,	130
Pore size,	Max. 80 , Min. 60

Fig. 4 shows a SEM photograph of the test dust that was generated during the transportation process of calcined clinkers. The operating condition is summarized in Table 2.

Table 2. Operating conditions of CYBAGFILTER.

Volumetric flow rate at outlet temp.(m^3/min)	306
Outlet temp.( )	45
Air-to-cloth ratio(m^3/m^2)	1.3
Differential pressure across filter media(mmH_2O)	65
Pulse pressure(kg/cm^2)	6
Pulse frequency(sec)	51
Pulse time(msec)	60

RESULTS AND DISCUSSION

Fluid Dynamics

The centrifugal, gravitational and inertial forces affect the flow pattern in the centrifugal. The flow is a very complicated turbulent flow including strong vortex, turbulent boundary flow along the wall of the outer tube of severe streamlining curvature, flow separation at the edge of the tube slope, low-Re flow, and vortex and separation at the wall of the inner tube. In order to simulate such a complicated turbulent flow more accurately, RNG(ReNomalization Group theory based) k-epsilon model was employed instead of general k-epsilon model. The RNG k-epsilon model includes the shear strain rate that the general k-epsilon model does not have. The FLUENT/UNS^{TM} Ver 4.2.8 code was used for computer simulation.

The magnitude of velocity and the vector distribution of velocity are shown in Fig. 5. Strong vortex is formed in the space between the inner and outer tubes and the flow goes up along the vortex axis from the bottom. This flow merges with the flow going up from the inner tube wall to the upper outer tube wall, and therefore the velocity at this point will increase. The turbulent kinematic energy is expected to become large at this area.

Fig. 6 shows the magnitude distribution of up-flow velocity. The whole areas except white-colored area near the center axis represent the distribution of velocity formed by the up-flow. The flow coming in from the inlet goes down with rotation by the rotation inertia and at the slope of the cone it starts to go up with rotation along the wall of the inner tube by the up-flow. The up-flow forms strong recirculation zone at the corner of junction to the outer tube wall, where it is highly expected that the flow will stay longer and therefore the dust particles will accumulate. After this point the up-flow changes the moving direction at the shell plate where the filters are attached and it starts to go down with rotation along the center. At this stage most of fibers are included in the down-flow velocity field with rotation, and the down-flow with rotation along the axis is maintained to the bottom of the cyclone. This helps dust particulates going down to the hopper.

Based on the above analytical results, overall fluid dynamic characteristic is depicted in Fig. 7. At the initial stage the phenomenon looks pretty much same as a standard centrifugal dust collector, however after the shell plate the rotating down-flow along the axis is formed.

Outlet Dust Concentration

Fig. 8 shows the size distribution of dust particles contained in the inlet and outlet gases. The size is measured in terms of the aerodynamic diameter, and expressed as dM/d log(Dp) in the figure. The dust concentration tended to increase with an increase of particle size since the mass of large particle is much bigger than that of small particle.

Collection Efficiency

According to results of experiments lasted for about 9 months, the outlet dust concentration ranged from $0.1mg/m^3$ to $0.5mg/m^3$ with an average of $0.23mg/m^3$. Fig. 9 shows the trend of the overall collection efficiency measured during December 1998 to July 1999. As shown in the figure the overall collection efficiency maintained 99.85 - 99.92%. This high efficiency resulted from low dust loading to the filter kept by the effective collection of dusts at the lower part of the apparatus.

Pressure Drop

The life of filter depends on the cleaning interval and the cleaning number. To prolong the filter life the abrasion caused by the contact between the filter and the bag cage should be avoided either by lengthening the cleaning interval or by reducing the cleaning number. To accomplish this purpose the increasing rate of the pressure drop must be kept slow by minimizing the dust loading to the filter. In case of CYBAGFILTER the filter life is expected to be much longer than that of general fabric filtration since 80% of dusts contained in the inlet gas is removed prior to entering the filter, i.e. only 20% of the dusts will be treated by the filter.

Fig. 10 shows pressure drop change of the test unit during the operation period. The pressure drop during the first one-month was low as 40mmH_2O, and after 7 months it was kept as a constant value of about 65mmH_2O. This observation indicates that it took about 7 months for the steady state dust cake and the residual dust cake to form. The reason for taking a longer time compared to the existing fabric filtration unit is that the dust loading to the filter was pretty low. This phenomenon was unique only to the test unit.

<u>Fractional Efficiency</u>

The fractional efficiency is a very important parameter that can be used as data to predict the outlet concentration of specific particle size. It has been reported that the most penetrating particle size (MPPS) becomes smaller at the faster filtration velocity[6)].

Fig. 11 shows the fractional efficiency during the operation period. Fig. 11(a) shows results after one month operation, where the fractional penetration at the MPPS of 0.9 was 2.3% and it was about 0.01% for particles larger than 1.5 . However, as shown in Fig. 11(b) and (c) after 2-month operation its value at the MPPS reduced to 0.35 - 0.55%. This phenomenon is due to the residual dust cake formed uniformly on the filter surface that attributed to the dust collection. The increase of the fractional penetration for the particle size of 5.0 10 might be ascribed to the passage of dust particles penetrated into the interior of the filter during the cleaning operation.

CONCLUSION

In this study a CYBAGFILTER unit of 18,000m^3/hr capacity installed in the clinker calcination process of Yongwal Ssangyong Cement Co. was tested for several months. Conclusion drawn from this work is summarized as follows;

1. It was confirmed that the dust cake after the cleaning step went down to the bottom of the CYBAGFILTER easily since the down-flow is formed along the axis as shown by the computational fluid dynamic simulation.
2. The outlet dust concentration of CYBAGFILTER was about 0.23mg/Sm^3 and the overall dust collection efficiency was kept as 99.9%.
3. The pressure drop of CYBAGFILTER after 7-month operation was kept as about 65mmH_2O. The filter life is expected to be prolonged since the cleaning interval was 20-

30 times longer than that of existing filtration apparatus.

4. The particle size at the most penetrating particle size was 0.9 during the first one month operation and tends to reduce to 0.3 -0.5 after one month operation.

In the future, a study on CYBAGFILTER module design will be performed to find optimum arrangement of each unit module. Also, design work on the structure to avoid abrasion by the large particle with high velocity will be pursued.

ACKNOWLEDGEMENT

This study was financially supported by the Ministry of Environment under the G-7 program.

REFERENCES

1. D. J. Helfritch and J. M. Quimby, "An Evaluation of a Pre-Charging Pulse-Jet Filter for Small Combustor Particulate Control", Research-Cottrell Environmental Services & Technologies, Somervill, NJ, DOE/PC/89807-T5(DE91015133), (April 1991).
2. S. J. Miller, G. L. Schelkoph, G. E. Dunham, K. Walker and H. Krigmont, "Advanced hybrid particulate collector, A new concept for air toxics and fine-particle control", EPRI-DOE-EPA Combined Utility, Air Pollutant Control Mega Sym., Washington, D.C., Aug. 25-29 (1997).
3. S. D. Kim, Y. O. Park, J. H. Lim, J. E. Son and D. K. Jung, 'Optimum Design of Inner Tube Type in KIER Type CYBAGFILTER', Theories and Application of Chemical Engineering, Proceedings of '98 KIChE fall meeting, 1998, Vol. 4, No. 2.
4. S. D. Kim, Y. O. Park, J. H. Lim, J. E. Son and D. K. Jung, 'Mathematical Simulation to Determine Optimum Module and fluid dynamic characteristics of KIER Type CYBAGFILTER', Theories and Application of Chemical Engineering, Proceedings of '98 KIChE fall meeting, 1999, Vol. 5, No. 1.
5. G. A. Brinchman, R. E. Gill and M. B. Hrycak, "The application of GORE-TEX Membrane Filter Bags at a Tire-to-Energy Facility", Incineration Conference Proceedings, Albuquerque, NM., pp.93-97 (1992).
6. C. Kanaoka, H. Emi and T. Myojo, "Simulation of the Growing Process of a Particle Dendrite and Evaluation of a Single Fiber Collection Efficiency with Dust Load", *Journal of Aerosol Science*, **11,** 377 (1979).

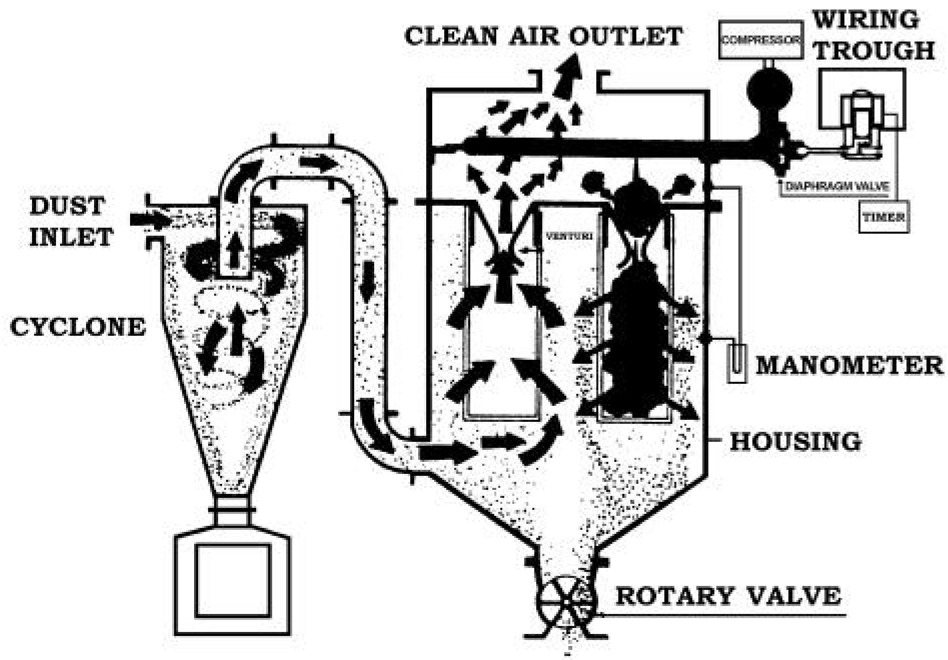


Fig. 1 Structure of existing bag filter.

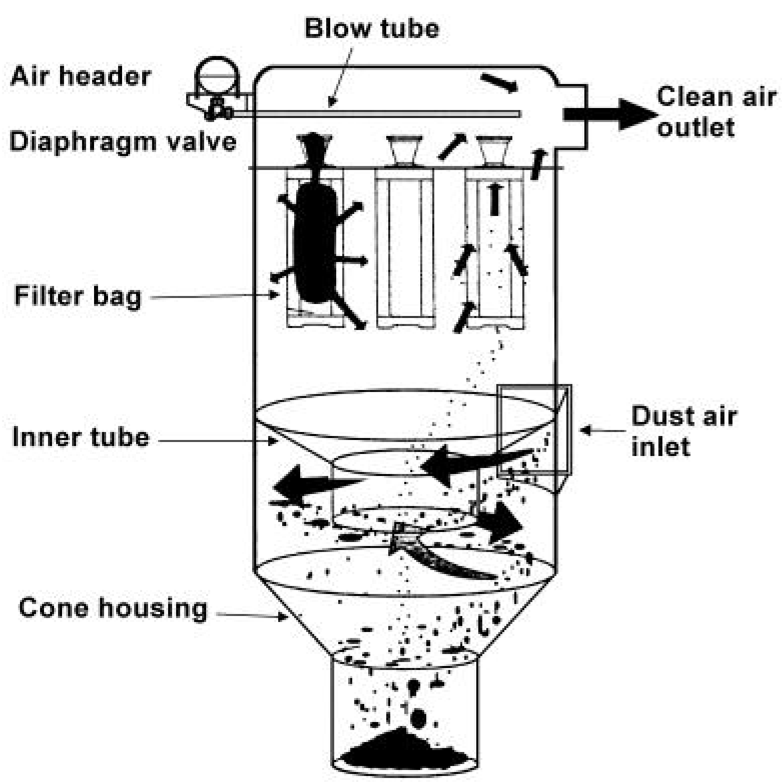
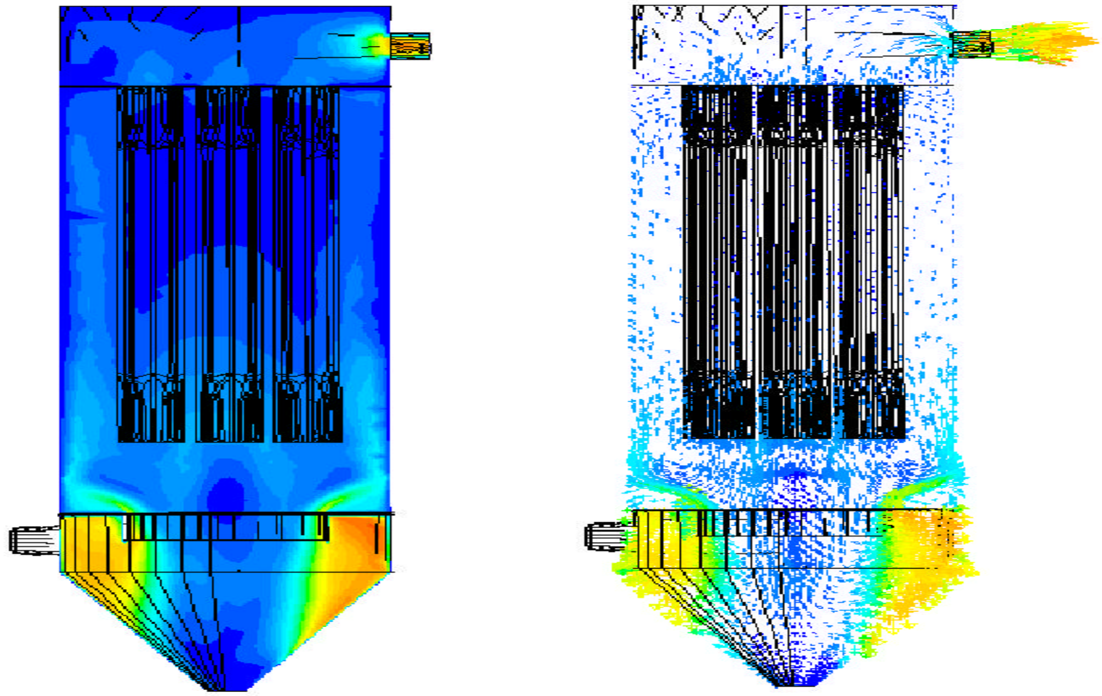


Fig. 2 Structure of KIER TYPE CYBAGFILTER.

Fig. 3 Photograph of CYBAGFILTER.

Fig. 4 SEM photograph of clinker dust (x 773)



(a) Velocity magnitude **(b) Velocity vector**

Fig. 5 Distributions of velocity magnitude and velocity vector.

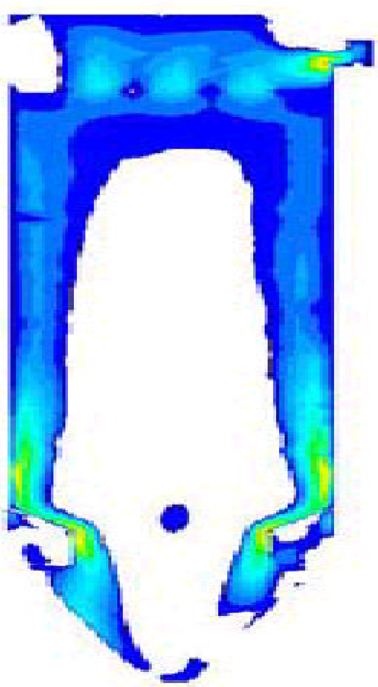


Fig. 6 Up-flow velocity magnitude distribution.

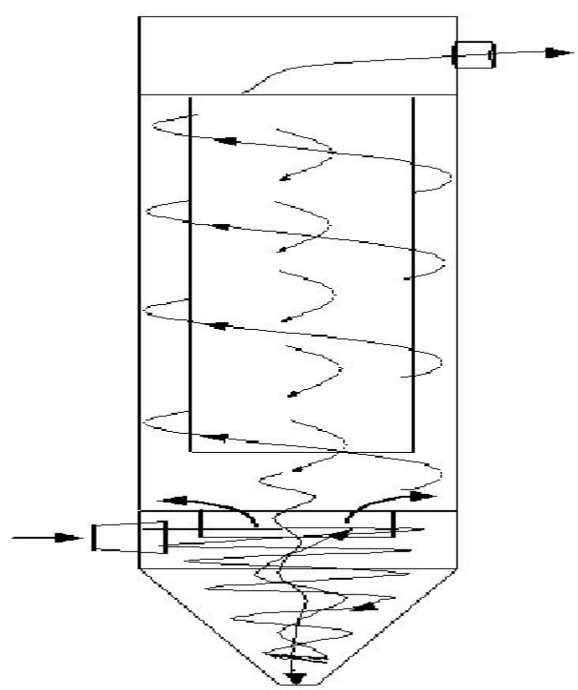


Fig. 7 Fluid dynamic characteristic of CYBAGFILTER.

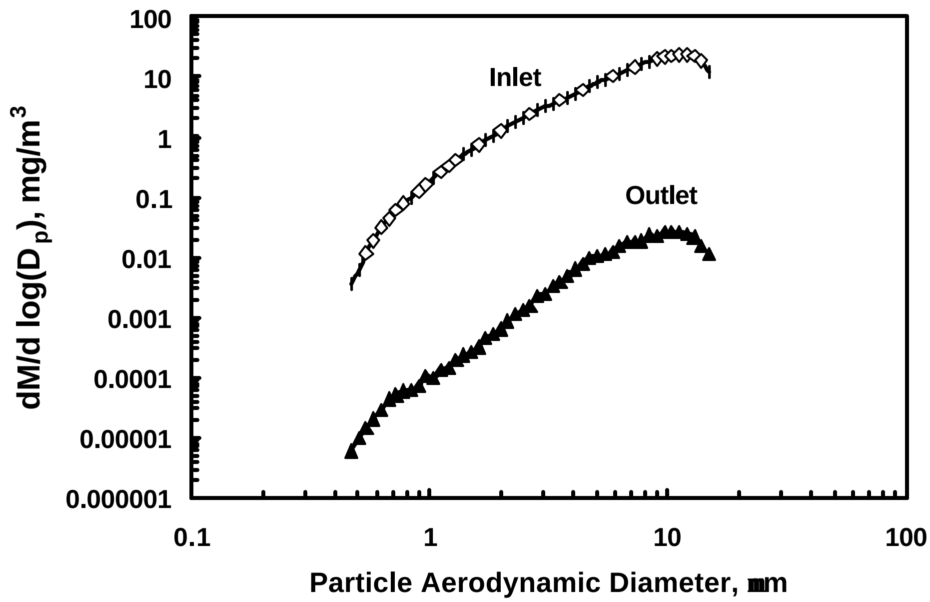


Fig. 8 Inlet and outlet particle size distributions.

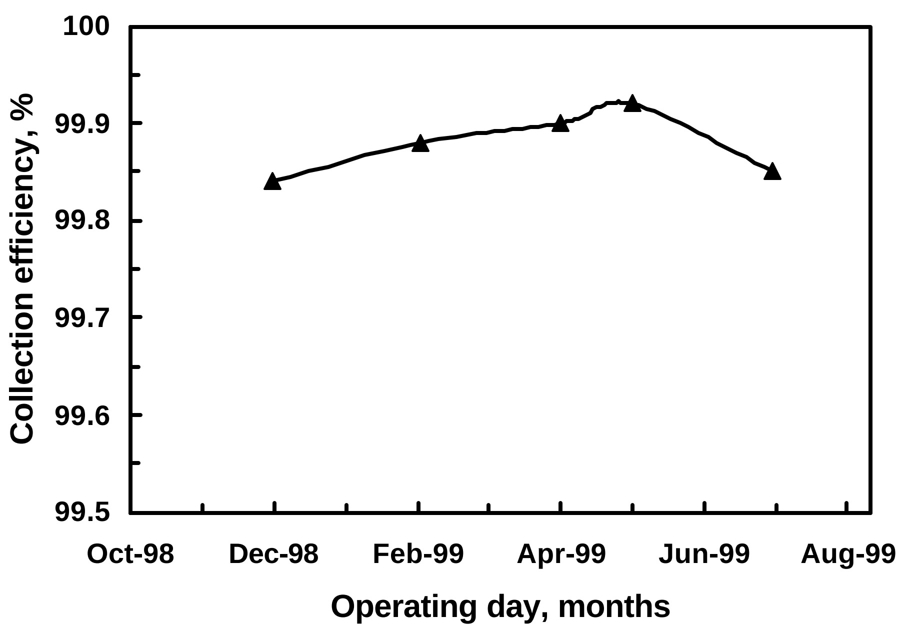


Fig. 9 Collection efficiency on the operating day.

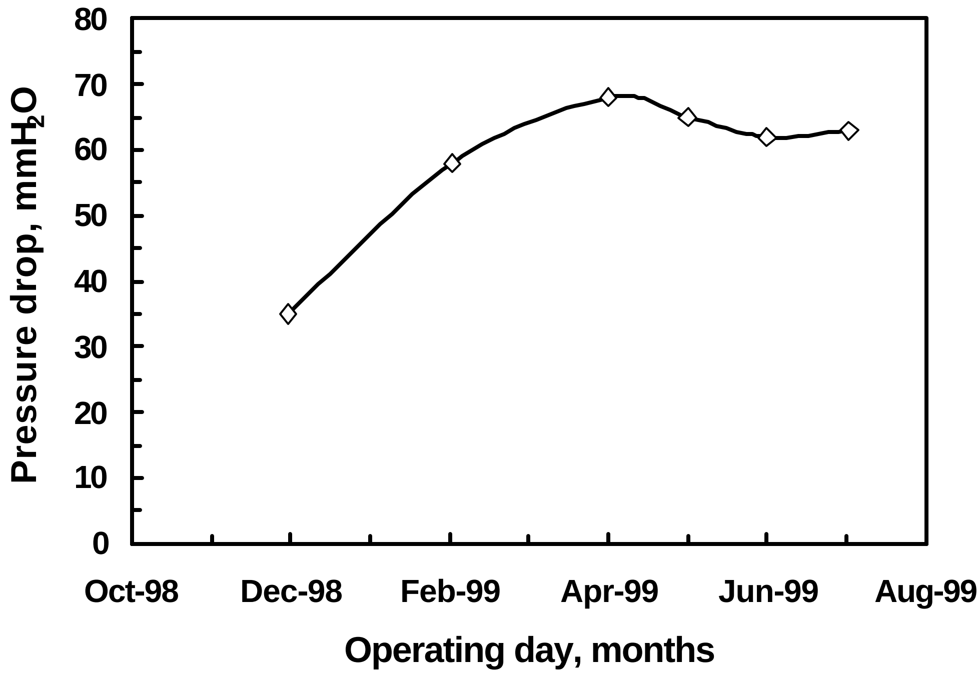
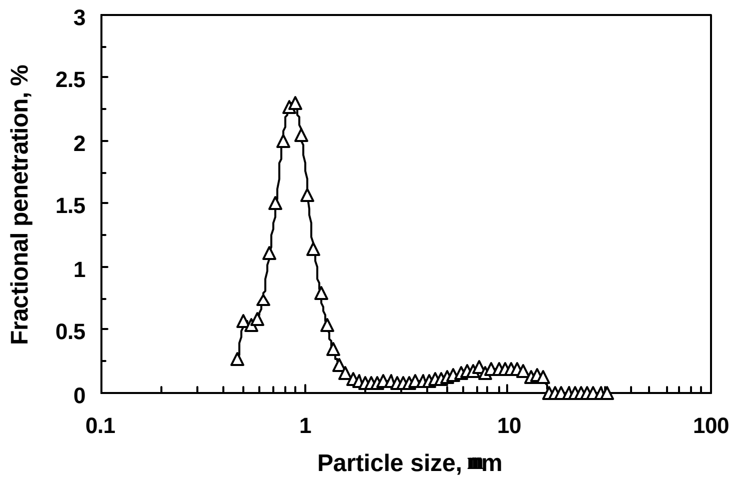
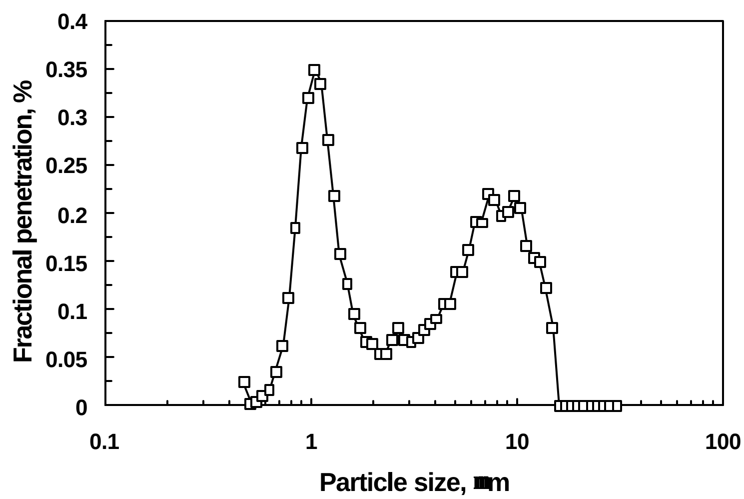


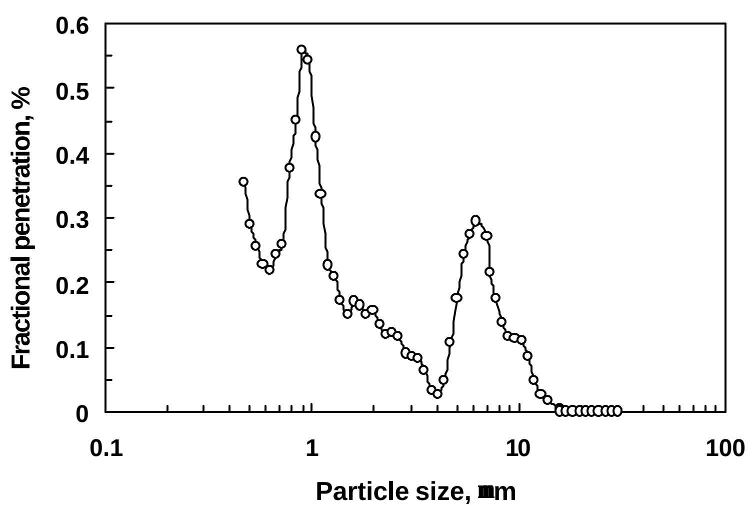
Fig. 10 Pressure drop on the operating day.



(a) Dec-1998(1)



(b) Dec-1998(2)



(c) May-1999

Fig. 11 Effect of fractional penetration.